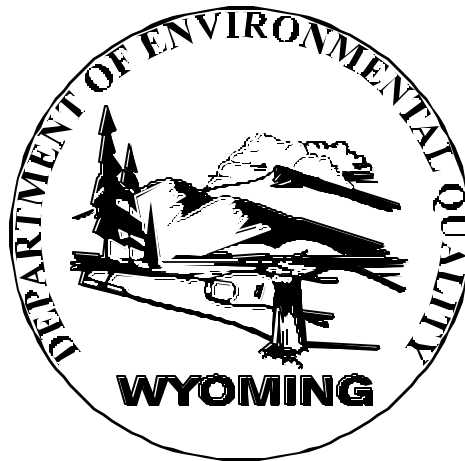


**WYOMING DEPARTMENT OF ENVIRONMENTAL QUALITY  
WATER QUALITY DIVISION**

**ANTIDEGRADATION  
REVIEW, ANALYSIS AND FINDINGS**



**CONCENTRATIONS OF BARIUM IN THE SURFACE WATERS  
IN NORTHEASTERN WYOMING  
RELATED TO  
DISCHARGES OF  
COAL BED METHANE PRODUCED WATER**



# **ANTIDEGRADATION REVIEW & FINDINGS**

**December 1, 2000**

## **Analysis of potential water quality degradation associated with barium concentrations resulting from coal bed methane development in northeastern Wyoming.**

### **I. EXECUTIVE SUMMARY**

The Petroleum Association of Wyoming (PAW) has requested the Wyoming Department of Environmental Quality, Water Quality Division (WQD) to consider allowing discharges of coal bed methane produced water that may result in increased barium concentrations in the receiving waters. The purpose of this review is to determine what levels of barium are acceptable and necessary in the surface waters in the Powder, Belle Fourche and Cheyenne River Basins taking into consideration reasonable treatment/disposal technologies available to the coal bed methane industry and designated uses of the receiving waters. Because barium concentrations are only relevant to the protection of drinking water supplies, this review will focus on Class 2 waters within the associated watersheds where there is a potential for this use.

The scope of this antidegradation review covers major portions of the Powder, Belle Fourche, and Cheyenne River Basins. These large basins have been divided into 8 smaller watershed units and the findings of this review apply only to those specifically identified watersheds. The draft document that was published for public review in December, 2000 originally identified 12 watershed segments. Because the mainstem streams in 4 of these watersheds have been reclassified from Class 2 to Class 3, those watershed segments have been consolidated into the nearest downstream Class 2 watershed resulting in 8 rather than 12 barium analysis areas. These include Donkey and Caballo Creeks which have been consolidated into the Upper Belle Fourche watershed and Antelope and Black Thunder Creeks which have been consolidated into the Cheyenne Watershed. This action has not resulted in a change in the proposed permitting strategy or end-of-pipe effluent limits for barium. It has eliminated the need for barium monitoring to occur in the smaller watersheds. The proposed in-stream barium thresholds will still be monitored at the indicated sampling stations on the associated Class 2 mainstem.

There are areas in northeastern Wyoming where coal bed methane development may occur that are not covered by this review. These include the entire Tongue River watershed, the Powder River watershed above the confluence of Salt Creek and the entire Little Missouri watershed within Wyoming.

For each of the 8 identified watersheds the background concentration of barium has been established based on stream sampling data recorded prior to 1985 to eliminate the influence of current coal bed methane development in the area. In general, the median barium values for the main stem streams in each watershed were used as the background quality. There is insufficient data available to calculate a median value in three of the defined watersheds. For the lower Belle Fourche segment (below Keyhole Reservoir), the background condition was assumed to be approximately the same as the upper Belle Fourche (above Keyhole Reservoir). Similarly, the lower Powder River segment (below Crazy Woman Creek) was

assumed to be approximately the same as the segment immediately above Crazy Woman Creek. The background concentration for Clear Creek was assumed to be approximately the same as Crazy Woman Creek based on an analysis of the major cation and anion concentrations in both. For most other constituents the quality in both watersheds was nearly the same, supporting the use of the Crazy Woman barium data for Clear Creek.

From the background data, the remaining assimilative capacity and a significance threshold concentration was calculated for each watershed. The significance threshold was established as 20% of the assimilative capacity plus the background for each watershed. The table below summarizes these values:

Seg.	Watershed	Background Conc. (ug/l)	Assimilative Capacity (ug/l)	Significance Threshold (ug/l)
1	Powder River - Middle	300	1700	640
2	Powder River - Lower	300	1700	640
3	Crazy Woman Creek	100	1900	480
4	Clear Creek	100	1900	480
5	Little Powder River	100	1900	480
6	Cheyenne River	200	1800	560
7	Belle Fourche - Upper	100	1900	480
8	Belle Fourche - Lower	100	1900	480

The Water Quality Division has determined that it is not necessary to allow barium degradation to exceed the significance threshold in any of the subject watersheds and still accommodate full development of the resource. This determination relies upon an assumption that most of the barium discharged will naturally attenuate through infiltration, ion exchange with stream sediments, and chemical precipitation as barium sulfate upon discharge to the surface. However, because these natural processes require both time and space, there may be temporary exceedences of the significance thresholds in some stream segments directly below CBM discharge outfalls.

A permitting strategy is presented that will ensure that the water quality in each affected watershed will:

1. Not exceed the 2000 ug/l human health criterion for barium on Class 2 waters;
2. Fully support all designated uses in relation to barium concentrations; and
3. Maintain barium degradation and risk to human health at insignificant levels.

This permitting strategy involves:

1. Setting an end of pipe effluent limit for barium at 1800 ug/l in all watersheds. This effluent limit would remain in effect unless the in-stream concentration exceeds the significance threshold in each watershed. This option relies on natural attenuation to achieve the significance thresholds. Soluble barium reacts readily with sulfates and carbonates naturally present in the surface waters in the area to form insoluble non-toxic compounds. It is expected that natural attenuation will effectively maintain water quality at acceptable levels.
2. Establishing an in-stream monitoring program to ensure that the desired effect occurs in each watershed. Specific monitoring locations have been identified in each of the 12 watershed segments. If monitoring shows that the significance levels are being exceeded, end-of-pipe limits on all new or renewed permits in the affected watershed segment will be modified as appropriate to bring the in-stream concentrations back to within the significance thresholds.

This permitting strategy will guarantee compliance with the 2000 ug/l standards at all times but there is a small possibility that the significance threshold may be temporarily exceeded if natural attenuation is less than expected. Based on water quality data from existing wells, less than 10% of all CBM discharges would initially require additional treatment or alternative disposal.

The Wyoming Department of Environmental Quality, Water Quality Division will implement the end-of-pipe effluent limits and the described permitting strategy for all coal bed methane discharges through the conditions and limitations on NPDES permits issued within the geographic scope of this antidegradation review. End-of-pipe means the final outfall from a well, collection of wells or treatment process (*if utilized*) prior to discharge to the receiving water.

## **II. PURPOSE**

The Wyoming surface water quality standards (*Chapter 1 of the Wyoming Water Quality Rules and Regulations*) classify waters according to designated uses and provide numeric criteria for a wide range of pollutants. These criteria establish measurable thresholds by which a water can be considered to be supporting or not supporting its designated uses. The state standards also include an antidegradation policy that is intended to maintain the existing quality of waters where the background concentrations of pollutants is better than the use-support criteria.

Class 2 waters are protected for fisheries and public drinking water uses and are considered to be high quality waters. The Water Quality Division may issue a permit or certification for new or increased discharges to these waters upon making a finding that the amount of resultant degradation is insignificant or that the discharge is necessary to accommodate important economic or social development in the area where the waters are located. The Department must also assure that the highest statutory and regulatory

requirements for all new and existing point sources and all cost effective and reasonable best management practices for nonpoint sources have been achieved.

The human health criterion for barium is 2000 micrograms/liter (ug/l) and is applicable on all Class 2 waters in the state. Background concentrations of barium in the Class 2 waters in northeastern Wyoming vary with location and flow conditions, but are generally better than the 2000 ug/l criterion. Median values measured or calculated from historic USGS data in the watersheds within the coal bed methane development area are all less than 300 ug/l.

The analysis and findings in this antidegradation review are based largely upon information submitted to the Department of Environmental Quality by the Petroleum Association of Wyoming in a report entitled *“Technical Support for Antidegradation for Barium”* (Camp Dresser & McKee, August 2000). This document is hereafter referred to as the “PAW report”. Copies of this report have been made available for review at the Water Quality Division offices in Cheyenne, Sheridan, and Lander and at the Sheridan, Johnson, Campbell, Crook, Weston, Converse and Niobrara County Libraries. The WQD offices are located on the fourth floor, west wing of the Herschler Building, 122 W. 25th Street in Cheyenne, 1043 Coffeen Ave, Suite D, in Sheridan and at the Key Bank Building in Lander.

### **III. BACKGROUND**

There is currently a significant interest in developing methane gas from the various coal formations underlying northeastern Wyoming. Methane is produced from the coal formations by pumping groundwater from the coal beds and thus relieving hydrostatic pressure on the coals. As pressure is lessened, methane is released from the coals and can be collected and piped to end users. The water that is produced in this manner is considered a “waste” under the Wyoming Environmental Quality Act and discharges to the surface are regulated through NPDES permits issued by the Water Quality Division.

At present over 10,000 methane gas wells have been permitted by the Wyoming Oil and Gas Commission in northeastern Wyoming and the industry foresees a potential for up to 30,000 wells to be eventually developed. Only a fraction of these wells have been drilled and are producing water and gas.

Much of the produced groundwater contains significantly higher concentrations of barium than is found naturally in the surface waters in the area. Barium is a non-priority pollutant which occurs in Wyoming waters from either natural or human-caused sources. There are adverse human health effects associated with elevated concentrations of barium, however, it is not believed to be a significant threat to aquatic life at concentrations that can potentially be achieved in surface water systems. Therefore, an aquatic life value for barium has not been developed.

The current Wyoming human health criterion of 2000 micrograms/liter (ug/l) is based on the Federal Safe Drinking Water Act Maximum Contaminant Level (MCL). The MCL represents the maximum concentration of a pollutant that is considered safe for public drinking water supplies. Except for the Town of Buffalo, there are no known public drinking water supplies utilizing surface water within the area

covered by this antidegradation review. Buffalo diverts its drinking water supply from Clear Creek and is upstream from any proposed coal bed methane development activity. The Tongue River watershed from which the municipalities of Sheridan, Dayton and Ranchester derive drinking water is not included in this review. The primary effect of the barium standard in the area is to protect potential future drinking water uses.

Though ingestion of soluble barium compounds may cause adverse gastrointestinal or central nervous system effects in humans, barium reacts readily with sulfate or carbonate in natural waters to form virtually insoluble, non-toxic compounds (EPA Gold Book, 1986). The surface waters in the coal bed methane development area generally have high background concentrations of sulfate. It is reasonable to conclude that a large portion of the soluble barium from CBM well discharges will naturally attenuate upon mixing with the receiving waters by forming inert barium sulfate.

#### **IV. REGULATORY BASIS**

Section 8 of Quality Standards for Wyoming Surface Waters (Water Quality Division Rules and Regulations, Chapter 1) establishes a regulatory policy concerning antidegradation. That regulation provides...

*Section 8. **Antidegradation.** Water uses in existence on or after November 28, 1975 and the level of water quality necessary to protect those uses shall be maintained and protected. Those surface waters not designated as Class 1, but whose quality is better than the standards contained in these regulations, shall be maintained at that higher quality. However, after full intergovernmental coordination and public participation, the Wyoming Department of Environmental Quality may issue a permit for or allow any project or development which would constitute a new source of pollution, or an increased source of pollution, to these waters as long as the following conditions are met:*

- (i) The quality is not lowered below these standards;*
  - (ii) All existing water uses are fully maintained and protected;*
  - (iii) The highest statutory and regulatory requirements for all new and existing point sources and all cost effective and reasonable best management practices for nonpoint sources have been achieved; and*
  - (iv) The lowered water quality is necessary to accommodate important economic or social development in the area in which the waters are located.*
- (b) The administrator may require an applicant to submit additional information, including but not limited to an analysis of alternatives to any proposed discharge and relevant economic information before making a determination under this section.*

(c) *The procedures used to implement this section are described in the "Antidegradation Implementation Policy."*

Prior to authorizing the discharge of coal bed methane produced water, the department must make an affirmative finding relative to each of the antidegradation elements listed as (a) through (d) above. Because of the large number of potential discharges, all of which are similar in nature, the department intends to implement the antidegradation provisions on a watershed basis rather than a permit by permit basis. This approach is better suited to addressing cumulative impacts of a large number of comparable discharges than assessing activities one-by-one. The findings of this review shall apply to NPDES permits for coal bed methane produced water discharges that occur within its geographic scope.

## **V. GEOGRAPHIC SCOPE**

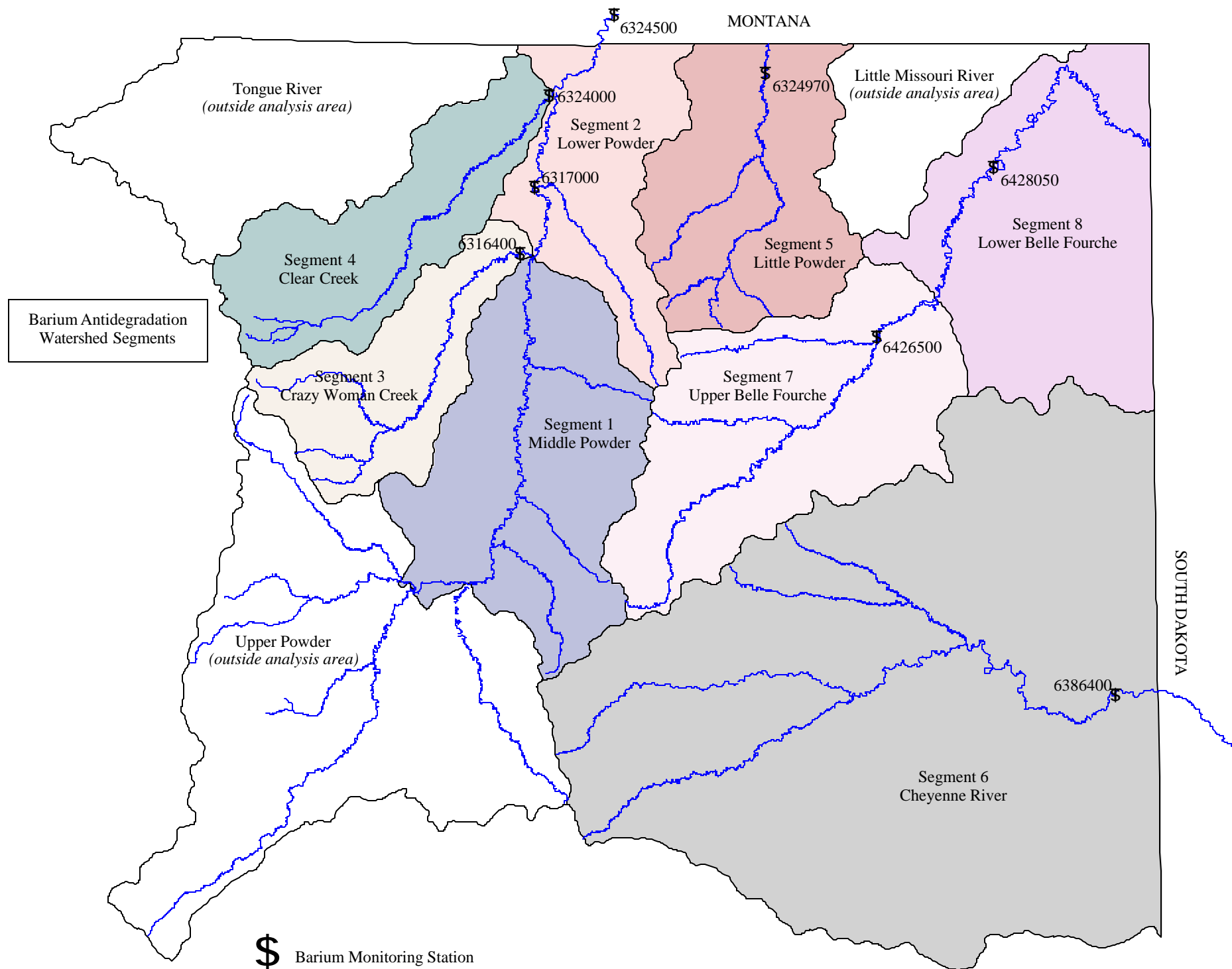
The geographic scope of this review includes eight sub-watersheds encompassing large portions of the Powder, Belle Fourche and Cheyenne River Basins. The twelve sub-watersheds are described as:

1. The Powder River Watershed below the confluence of Salt Creek and above the confluence of Crazy Woman Creek;
2. The Powder River below the confluence of Crazy Woman Creek to the Montana state line;
3. The Crazy Woman Creek Watershed;
4. The Clear Creek Watershed;
5. The Little Powder River Watershed within Wyoming;
6. The Cheyenne River Watershed
7. The Belle Fourche River Watershed above Keyhole Reservoir;
8. The Belle Fourche Watershed below Keyhole Reservoir to the South Dakota state line;

Each of the watersheds listed above are considered individually and though much of the information may be similar among the various segments, this review is essentially a compilation of eight separate determinations. The information and findings that are similar across all watersheds is discussed in section VI. of this document entitled "Area Wide Findings". Agency determinations in this section apply globally across the geographic scope. Section VII contains watershed-specific information and findings.

The analysis and findings in this antidegradation review are based largely upon information submitted to the Department of Environmental Quality by the Petroleum Association of Wyoming in a report entitled "*Technical Support for Antidegradation for Barium*" (Camp Dresser & McKee, August, 2000).





## SECTION VI. AREA WIDE FINDINGS

Pursuant to the antidegradation provisions in Chapter 1, Section 8, the Department must make four findings before authorizing an activity that will result in lowered water quality. Prior to the issuance of NPDES permits containing concentrations of barium, the department must find:

1. *That the quality is not lowered below the adopted standards;*

The applicable standard for barium is 2000 ug/l. This value represents an in-stream concentration and not an effluent or end-of-pipe concentration. The department may allow an effluent limit that is higher than the 2000 ug/l in circumstances where mixing with the receiving water would provide sufficient dilution to ensure that the in-stream concentration remains below 2000 ug/l.

Because of uncertainties regarding available dilution in the receiving waters and total coal bed methane discharge volumes, the Department shall in no case allow an end of pipe concentration to exceed 2000 ug/l. From a simple mass balance perspective, an effluent limit of 2000 ug/l should ensure that the resulting in-stream concentrations will not exceed that limit. Any concentrating effects of evaporation would be offset by chemical precipitation of barium sulfate and carbonate compounds. Additionally, a large percentage of CBM wells produce water that is significantly less than 2000 ug/l barium and these discharges would serve to dilute those that are close to 2000.

Therefore, restricting all discharges to less than 2000 ug/l will ensure that the quality of all receiving waters will not be lowered below the adopted standards.

2. *That all existing water uses are fully maintained and protected;*

The 2000 ug/l standard for barium is intended to fully support the use of the water for public drinking water supplies. At this level, all other water uses (aquatic life, recreation, wildlife, agriculture etc.) will also be fully supported.

3. *That the highest statutory and regulatory requirements for all new and existing point sources and all cost effective and reasonable best management practices for nonpoint sources have been achieved;*

This requirement is primarily intended to ensure that proposed activities that will result in water quality degradation for a particular parameter will not be authorized where there are existing unresolved compliance problems involving the same parameter in the zone of influence of the proposed activity. The "zone of influence" is determined as appropriate for the parameter of concern, the characteristics of the receiving water (e.g. lake versus river, etc.), and other relevant factors.

The "highest statutory and regulatory requirements" for point sources refers to any federal effluent limitations under sections 301 and 306 of the federal Clean Water Act that may apply to the

category of discharge. There are no applicable federal effluent limitations for barium. Additionally, background concentrations of barium in all of the waters surveyed in the associated basins are low and there is no indication of any significant level of barium from nonpoint sources. Therefore, this requirement will be met under any level of development.

4. *That the lowered water quality is necessary to accommodate important economic or social development in the area in which the waters are located.*

The antidegradation review under this part consists of three sequential evaluations, 1.) Determination of significance; 2.) Economic evaluation; and 3.) Examination of alternatives. There are both area-wide and watershed-specific determinations made under this part. In general, the assessment of significance, economic evaluation and examination of available alternatives and technology has been disclosed on an area-wide basis because the circumstances are similar across the entire development area. A determination of what level of degradation is necessary, however, has been made on a watershed basis because of differences in background concentrations of barium, available assimilative capacity and CBM well discharge quality.

#### Determination of Significance:

As a matter of policy, the Department of Environmental Quality considers a lowering of water quality that consumes 20% or more of the available assimilative capacity for the parameter of concern (*barium*) to be “significant”. Assimilative capacity is the increment in terms of concentration between the pre-CBM background water quality and the numeric standard for barium (2000 ug/l).

Though some percentage of the CBM wells contain concentrations of barium that are within the 20% assimilative capacity threshold, it is possible that the cumulative effect of all discharges may raise in-stream concentrations above the threshold in each watershed. This projection is based on water quality data from existing CBM wells provided in the PAW report. Therefore, potential degradation due to barium is considered significant and an economic analysis and examination of alternatives have been developed to help identify the level of degradation that is necessary.

#### Economic Evaluation:

The economic evaluation concerns whether or not the proposed activity represents important economic or social development in the area where the waters are located. For purposes of this evaluation, the area where the impacted waters are located are the lands and communities within the watershed boundaries described above in Section IV - Geographic Scope. This area includes all of Campbell County and major portions of Sheridan, Johnson, Crook, Weston, Converse, and Niobrara Counties, Wyoming.

Normally, in making a determination of whether an activity constitutes “important economic or social development”, it shall be presumed important unless information to the contrary is submitted in the public review process. The proposed coal bed methane development in northeastern Wyoming can

clearly be considered important economic development. An economic analysis is included in the report submitted by the Petroleum Association of Wyoming (PAW). This analysis is based on the potential development of 30,000 coal bed methane wells and included an estimation of tax revenues to the State as well as the economic significance to the local communities in terms of capital expenditures and job creation.

The table below shows a summary of the potential area-wide tax and royalties revenue generation to the State:

Acreage Split	%	No. Wells	Tax & Royalties/Well	Total Proceeds to State
Federal Lease	56	16,800	\$80,562	\$1,353,000,000
Fee Lease	38	11,400	\$60,528	\$690,000,000
State Lease	6	1,800	\$130,440	235,000,000
Total				\$2,278,000,000

- from the PAW report, August 2000 -

The PAW report also estimates total capital investment for full field development (30,000 wells) to be approximately \$3.625 billion in the counties where the development occurs. This figure represents a 10-year investment assuming the development of 3,000 wells/year. A 3,000 well/year development rate would create 125 jobs and a total yearly payroll of \$7.5 million.

### Alternatives

Because the proposed activity is determined to be important economic or social development, a determination needs to be made as to whether the potential degradation (*measured as increased concentration of barium*) that would result from coal bed methane discharges is necessary to accommodate that development. In making this determination, the projected level of degradation shall be considered acceptable if there are no reasonable water quality control alternatives available that would result in less degradation of the state waters. To be considered, alternatives must be economically, environmentally and technologically feasible and that the expected environmental benefits justifies the cost of implementation. Furthermore, the scope of alternatives considered is limited to those that would accomplish the proposed activity's purpose.

In determining the economic feasibility of water quality control alternatives, the Administrator may use some of the following factors to weigh the reasonableness of the various alternatives. [start here]

- Whether the costs of the alternative significantly exceed the costs of the proposal;
- Whether the treatment alternative represents costs that significantly exceed costs for other similar dischargers to similar stream classes, or standard industry practices.

- Whether the cost of implementation is justified by the environmental benefits gained.
- Any other environmental benefits, unrelated to water quality which may result from each of the alternatives examined.

Sixteen conceptual alternatives to direct discharge of CBM produced water were screened for feasibility in the PAW report. These 16 alternatives can be separated into 3 general categories: active treatment with surface discharge; passive treatment with surface discharge (BMPs); and non-discharge alternatives.

This initial screening options were evaluated and narrowed to an identification of 4 potentially applicable options based on barium removal effectiveness and cost feasibility. Of these, there were no passive treatment alternatives that would effectively remove barium to desired levels. The four technologies concluded to be the most feasible included two active treatment options and two non-discharge options. The active treatment alternatives evaluated in detail were chemical precipitation and ion exchange and the non-discharge alternatives were well injection and shallow infiltration (leach fields) options.

Chemical precipitation and ion exchange could be theoretically applied to all discharges in all watersheds while the reinjection and infiltration options may be restricted on a localized basis by the availability of suitable receiving aquifers for well injection or land availability and suitable soil types for infiltration. All options would result in increased operational costs and depending upon the market price for methane may be economically infeasible. The table below shows a summary of the estimated minimum and maximum cost/MCF of gas produced for each alternative.

Alternative	Minimum Cost (\$/MCF)	Maximum Cost (\$/MCF)
Chemical Precipitation	\$0.67	\$1.07
Ion Exchange	\$0.83	\$1.42
Reinjection	\$0.87	\$1.23
Infiltration	\$0.12	\$0.22

Market prices for methane are relatively dynamic and have ranged from approximately \$1.60/MCF to over \$4.00/MCF in 1999 and 2000 respectively. At \$1.60/MCF the net profit to the producer is \$0.45 to \$0.50/MCF making the first three options clearly infeasible. The added costs of the infiltration option are within the profit margin but would reduce the investor's rate of return to such an extent that CBM development would not be attractive. At a market price of \$4.00/MCF, however, implementation of the most expensive option (ion exchange at \$1.42/MCF) may yield a net profit of \$1.43/MCF and could provide a sufficient rate of return to support full development of the resource. At current market prices for methane, all 4 treatment or disposal options may be economically feasible.

## SECTION VII. WATERSHED-SPECIFIC FINDINGS

As indicated in Section VI of this review document, the coal bed development area has been separated into 12 sub-watersheds for management purposes. Because there are differences in both the background water quality, CBM discharge barium concentrations, and assimilative capacity, separate antidegradation findings and threshold values are proposed for each sub-watershed.

### Segment 1. Middle Powder River - The Powder River Watershed below the confluence of Salt Creek and above the confluence of Crazy Woman Creek.

	Background Barium Conc. (ug/l)	CBM Well Barium Conc. (ug/l)	Assimilative Capacity (ug/l)	20% of Assimilative Capacity (ug/l)	In-stream Significance Threshold (ug/l)	Projected Maximum Barium Conc. In-stream (ug/l)
Min	100	200				
Max	900	2110				
Median	300	1200	1700	340	640	
Mean	336	1178				
Std Dev	210	569				
Low Flow	36	1800				1781 <sup>1</sup>
Mean Flow	332	1800				1275 <sup>1</sup>
Mean Flow	332	1178 <sup>2</sup>				875 <sup>3</sup>

<sup>1</sup> Based on a mass balance calculation considering the maximum discharge from 5349 CBM wells at the referenced background flow condition. In this watershed, a correlation exists between flow and barium concentration [ $\text{Total Barium (ug/l)} = 1.52 \times \text{Flow (cfs)} + 29.7$ ]. The background barium concentrations based on this correlation and the maximum allowable end-of-pipe concentration were used for this calculation. Calculation does not consider attenuation of barium due to ion exchange with stream sediments, chemical precipitation or infiltration. Actual resulting in-stream concentrations will be significantly lower. Also assumes all wells contain a barium concentration of 1800 ug/l. The figure represents the worst case for the associated flow condition.

<sup>2</sup> Mean barium value recorded for active wells operating in this watershed.

<sup>3</sup> Calculation does not consider attenuation of barium due to ion exchange with stream sediments, chemical precipitation or infiltration.

Based on the likelihood of a large degree of natural attenuation and the availability of alternative treatment or disposal options for the small percentage of wells that will require such handling, the Department finds that it is not necessary to allow barium degradation to exceed the in-stream significance threshold of 640 ug/l in the Powder River watershed between Salt Creek and Crazy Woman Creek. An NPDES permitting strategy for maintaining barium concentrations within the significance threshold includes:

- ! Limiting end-of-pipe discharges to 1800 ug/l and average in-stream concentrations to 640 ug/l as measured at the USGS gaging station on the Powder River at Arvada (station # 06317000). Under this option, approximately 19% of the CBM wells in the watershed would require additional treatment or alternative disposal. Approximately 81% could

discharge untreated water as long as the average in-stream concentration does not exceed 640 ug/l. It is likely that because of naturally occurring chemical precipitation, ion exchange and infiltration, the average in-stream concentration will not reach 640 ug/l.

**!** If the average barium concentration of four consecutive sampling periods equals or exceeds 640 ug/l, permitted discharges would be allowed to continue at up to 1800 ug/l for the term of the active permit. Effluent limits on new or renewed permits will be adjusted as necessary to bring the in-stream barium concentrations back within the significance threshold of 640 ug/l. For purposes of this calculation, sampling periods shall not be more frequent than monthly nor less frequent than quarterly.

**Segment 2. Lower Powder River - The Powder River below the confluence of Crazy Woman Creek to the Montana state line.**

	Background Barium Conc. <sup>1</sup> (ug/l)	CBM Well Barium Conc. (ug/l)	Assimilative Capacity (ug/l)	20% of Assimilative Capacity (ug/l)	In-stream Significance Threshold (ug/l)	Projected Maximum Barium Conc. In-stream (ug/l)
Min		180				
Max		3240				
Median	300	600	1700	340	640	
Mean		855				
Std Dev		660				
Low Flow	300	1800				1791 <sup>2</sup>
Mean Flow	300	1800				913 <sup>2</sup>
Mean Flow	300	855 <sup>3</sup>				527 <sup>4</sup>

<sup>1</sup> Actual sampling data for barium is not available for this segment of the Powder River. Therefore, the median barium value for the adjacent upstream reach (Segment 1) was used to determine available assimilative capacity and the threshold of significant degradation.

<sup>2</sup> Based on a mass balance calculation considering the maximum discharge from 2877 CBM wells at the referenced flow condition. The median background concentration and the maximum allowable end-of-pipe concentration were used for this calculation. Calculation does not consider attenuation of barium due to ion exchange with stream sediments, chemical precipitation or infiltration. Actual resulting in-stream concentrations will be significantly lower. Also assumes all wells contain a barium concentration of 1800 ug/l. The figure represents the worst case for the associated flow condition..

<sup>3</sup> Mean barium value recorded for active wells operating in this watershed.

<sup>4</sup> Calculation does not consider attenuation of barium due to ion exchange with stream sediments, chemical precipitation or infiltration.

Based on the likelihood of a large degree of natural attenuation and the availability of alternative treatment or disposal options for the small percentage of wells that will require such handling, the Department finds that it is not necessary to allow barium degradation to exceed the in-stream significance threshold of 640

ug/l in the Powder River watershed between Crazy Woman Creek and the Montana State line. An NPDES permitting strategy for maintaining barium concentrations within the significance threshold includes:

- ! Limiting end-of-pipe discharges to 1800 ug/l and average in-stream concentrations to 640 ug/l as measured at the USGS gaging station on the Powder River at Moorehead, Montana (station # 06324500). Under this option, approximately 8% of the CBM wells in the watershed would require additional treatment or alternative disposal. Approximately 92% could discharge untreated water as long as the average in-stream concentration does not exceed 640 ug/l. It is likely that because of naturally occurring chemical precipitation, ion exchange and infiltration, the average in-stream concentration will not reach 640 ug/l.
- ! If the average barium concentration of four consecutive sampling periods equals or exceeds 640 ug/l, permitted discharges would be allowed to continue at up to 1800 ug/l for the term of the active permit. Effluent limits on new or renewed permits will be adjusted as necessary to bring the in-stream barium concentrations back within the significance threshold of 640 ug/l. For purposes of this calculation, sampling periods shall not be more frequent than monthly nor less frequent than quarterly.

### Segment 3. The Crazy Woman Watershed.

	Background Barium Conc. (ug/l)	CBM Well Barium Conc. (ug/l) <sup>1</sup>	Assimilative Capacity (ug/l)	20% of Assimilative Capacity (ug/l)	In-stream Significance Threshold (ug/l)	Projected Maximum Barium Conc. In-stream (ug/l)
Min	100					
Max	200					
Median	100		1900	380	480	
Mean	120					
Std Dev	40					
Low Flow	100	1800				1800 <sup>2</sup>
Mean Flow	100	1800				961 <sup>2</sup>

<sup>1</sup> Actual CBM well data for barium is not available for the Crazy Woman watershed.

<sup>2</sup> Based on a mass balance calculation considering the maximum discharge from 1675 CBM wells at the referenced flow condition. The median background concentration and the maximum allowable end-of-pipe concentration were used for this calculation. Calculation does not consider attenuation of barium due to ion exchange with stream sediments, chemical precipitation or infiltration. Actual resulting in-stream concentrations will be significantly lower. Also assumes all wells contain a barium concentration of 1800 ug/l. The figure represents the worst case for the associated flow condition.

Based on the likelihood of a large degree of natural attenuation and the availability of alternative treatment or disposal options for the small percentage of wells that will require such handling, the Department finds that it is not necessary to allow barium degradation to exceed the in-stream significance threshold of 480



ug/l in the Crazy Woman Creek watershed. An NPDES permitting strategy for maintaining barium concentrations within the significance threshold includes:

! Limiting end-of-pipe discharges to 1800 ug/l and average in-stream concentrations to 480 ug/l as measured at the USGS gaging station on Crazy Woman Creek near Arvada (station # 06316400). Because actual CBM well quality data is not available for this segment, the percentage of wells that will require additional treatment or alternative disposal cannot be calculated. It is likely that because of naturally occurring chemical precipitation, ion exchange and infiltration, the average in-stream concentration will not reach 480 ug/l.

! If the average barium concentration of four consecutive sampling periods equals or exceeds 480 ug/l, permitted discharges would be allowed to continue at up to 1800 ug/l for the term of the active permit. Effluent limits on new or renewed permits will be adjusted as necessary to bring the in-stream barium concentrations back within the significance threshold of 480 ug/l. For purposes of this calculation, sampling periods shall not be more frequent than monthly nor less frequent than quarterly.

#### **Segment 4. The Clear Creek watershed in its entirety.**

	Background Barium Conc. (ug/l) <sup>1</sup>	CBM Well Barium Conc. (ug/l) <sup>2</sup>	Assimilative Capacity (ug/l)	20% of Assimilative Capacity (ug/l)	In-stream Significance Threshold (ug/l)	Projected Maximum Barium Conc. In-stream (ug/l)
Min						
Max						
Median	100		1900	380	480	
Mean						
Std Dev						
Low Flow	100	1800				1800 <sup>3</sup>
Mean Flow	100	1800				612 <sup>3</sup>

<sup>1</sup> Actual sampling data for barium is not available for the Clear Creek watershed. Therefore, the median barium value for the Crazy Woman watershed was used to determine available assimilative capacity and the threshold of significant degradation. Though barium data is not available in Clear Creek, a comparison of the major cation and anion concentrations in Crazy Woman and Clear Creeks shows that they have very similar water quality.

<sup>2</sup> Actual CBM well data for barium is not available for the Clear Creek watershed.

<sup>3</sup> Based on a mass balance calculation considering the maximum discharge from 2415 CBM wells at the referenced flow condition. The median background concentration and the maximum allowable end-of-pipe concentration were used for this calculation. Calculation does not consider attenuation of barium due to ion exchange with stream sediments, chemical precipitation or infiltration. Actual resulting in-stream concentrations will be significantly lower. Also assumes all wells contain a barium concentration of 1800 ug/l. The figure represents the worst case for the associated flow condition.

Based on the likelihood of a large degree of natural attenuation and the availability of alternative treatment or disposal options for the small percentage of wells that will require such handling, the Department finds that it is not necessary to allow barium degradation to exceed the in-stream significance threshold of 480 ug/l in the Clear Creek watershed. An NPDES permitting strategy for maintaining barium concentrations within the significance threshold includes:

- ! Limiting end-of-pipe discharges to 1800 ug/l and average in-stream concentrations to 480 ug/l as measured at the USGS gaging station on Clear Creek near Arvada (station # 06324000). Because actual CBM well quality data is not available for this segment, the percentage of wells that will require additional treatment or alternative disposal cannot be calculated. It is likely that because of naturally occurring chemical precipitation, ion exchange and infiltration, the average in-stream concentration will not reach 480 ug/l.
- ! If the average barium concentration of four consecutive sampling periods equals or exceeds 480 ug/l, permitted discharges would be allowed to continue at up to 1800 ug/l for the term of the active permit. Effluent limits on new or renewed permits will be adjusted as necessary to bring the in-stream barium concentrations back within the significance threshold of 480 ug/l. For purposes of this calculation, sampling periods shall not be more frequent than monthly nor less frequent than quarterly.

#### **Segment 5. The Little Powder River Watershed within Wyoming.**

	Background Barium Conc. (ug/l)	CBM Well Barium Conc. (ug/l)	Assimilative Capacity (ug/l)	20% of Assimilative Capacity (ug/l)	In-stream Significance Threshold (ug/l)	Projected Maximum Barium Conc. In-stream (ug/l)
Min	30	100				
Max	900	2000				
Median	100	1080	1900	380	480	
Mean	149	1074				
Std Dev	151	505				
Low Flow	100	1800				1800 <sup>1</sup>
Mean Flow	100	1800				1209 <sup>1</sup>
Mean Flow	100	1074 <sup>2</sup>				735 <sup>3</sup>

<sup>1</sup> Based on a mass balance calculation considering the maximum discharge from 1900 CBM wells at the referenced flow condition. The median background concentration and the maximum allowable end-of-pipe concentration were used for this calculation. Calculation does not consider attenuation of barium due to ion exchange with stream sediments, chemical precipitation or infiltration. Actual resulting in-stream concentrations will be significantly lower. Also assumes all wells contain a barium concentration of 1800 ug/l. The figure represents the worst case for the associated flow condition.

<sup>2</sup> Mean barium value recorded for active wells operating in this watershed.

<sup>3</sup> Calculation does not consider attenuation of barium due to ion exchange with stream sediments, chemical precipitation or infiltration.

Based on the likelihood of a large degree of natural attenuation and the availability of alternative treatment or disposal options for the small percentage of wells that will require such handling, the Department finds that it is not necessary to allow barium degradation to exceed the in-stream significance threshold of 480 ug/l in the Little Powder River watershed. An NPDES permitting strategy for maintaining barium concentrations within the significance threshold includes:

- ! Limiting end-of-pipe discharges to 1800 ug/l and average in-stream concentrations to 480 ug/l as measured at the USGS gaging station on the Little Powder River above Dry Creek near Weston (station # 06324970). Under this option, approximately 9% of the CBM wells in the watershed would require additional treatment or alternative disposal. Approximately 91% could discharge untreated water as long as the average in-stream concentration does not exceed 480 ug/l. It is likely that because of naturally occurring chemical precipitation, ion exchange and infiltration, the average in-stream concentration will not reach 480 ug/l.
- ! If the average barium concentration of four consecutive sampling periods equals or exceeds 480 ug/l, permitted discharges would be allowed to continue at up to 1800 ug/l for the term of the active permit. Effluent limits on new or renewed permits will be adjusted as necessary to bring the in-stream barium concentrations back within the significance threshold of 480 ug/l. For purposes of this calculation, sampling periods shall not be more frequent than monthly nor less frequent than quarterly.

#### **Segment 6. The Cheyenne River Watershed.**

	Background Barium Conc. (ug/l)	CBM Well Barium Conc. (ug/l) <sup>1</sup>	Assimilative Capacity (ug/l)	20% of Assimilative Capacity (ug/l)	In-stream Significance Threshold (ug/l)	Projected Maximum Barium Conc. In-stream (ug/l)
Min	100	255				
Max	200	1120				
Median	200	531	1800	360	560	
Mean	167	578				
Std Dev	47	211				
Low Flow	200	1800				1800 <sup>1</sup>
Mean flow	200	1800				1670 <sup>1</sup>
Mean flow	200	578 <sup>2</sup>				527 <sup>3</sup>

<sup>1</sup> Based on a mass balance calculation considering the maximum discharge from 2688 CBM wells at the referenced flow condition. The median background concentration and the maximum allowable end-of-pipe concentration were used for this calculation. Calculation does not consider attenuation of barium due to ion exchange with stream sediments, chemical precipitation or infiltration. Actual

resulting in-stream concentrations will be significantly lower. Also assumes all wells contain a barium concentration of 1800 ug/l. The figure represents the worst case for the associated flow condition.

<sup>2</sup> Mean barium value recorded for active wells operating in this watershed.

<sup>3</sup> Calculation does not consider attenuation of barium due to ion exchange with stream sediments, chemical precipitation or infiltration.

Based on the likelihood of a large degree of natural attenuation and the availability of alternative treatment or disposal options for the small percentage of wells that will require such handling, the Department finds that it is not necessary to allow barium degradation to exceed the in-stream significance threshold of 560 ug/l in the Cheyenne River watershed. An NPDES permitting strategy for maintaining barium concentrations within the significance threshold includes:

- ! Limiting end-of-pipe discharges to 1800 ug/l and average in-stream concentrations to 560 ug/l as measured at the USGS gaging station on the Cheyenne River at Riverview (station # 06386400). Under this option, 100% of the CBM wells in the watershed could discharge untreated water as long as the average in-stream concentration does not exceed 560 ug/l. It is likely that because of naturally occurring chemical precipitation, ion exchange and infiltration, the average in-stream concentration will not reach 560 ug/l.
- ! If the average barium concentration of four consecutive sampling periods equals or exceeds 560 ug/l, permitted discharges would be allowed to continue at up to 1800 ug/l for the term of the active permit. Effluent limits on new or renewed permits will be adjusted as necessary to bring the in-stream barium concentrations back within the significance threshold of 560 ug/l. For purposes of this calculation, sampling periods shall not be more frequent than monthly nor less frequent than quarterly.

## Segment 7. Upper Belle Fourche - The Belle Fourche River Watershed above Keyhole Reservoir.

	Background Barium Conc. (ug/l)	CBM Well Barium Conc. (ug/l)	Assimilative Capacity (ug/l)	20% of Assimilative Capacity (ug/l)	In-stream Significance Threshold (ug/l)	Projected Maximum Barium Conc. In-stream (ug/l)
Min	100	100				
Max	200	1100				
Median	100	570	1900	380	480	
Mean	107	570				
Std Dev	26	244				
Low Flow	100	1800				1800 <sup>1</sup>
Mean Flow	100	1800				1635 <sup>1</sup>
Mean Flow	100	570 <sup>2</sup>				542 <sup>3</sup>

<sup>1</sup> *Based on a mass balance calculation considering the maximum discharge from 3096 CBM wells at the referenced flow condition. The median background concentration and the maximum allowable end-of-pipe concentration were used for this calculation. Calculation does not consider attenuation of barium due to ion exchange with stream sediments, chemical precipitation or infiltration. Actual resulting in-stream concentrations will be significantly lower. Also assumes all wells contain a barium concentration of 1800 ug/l. The figure represents the worst case for the associated flow condition.*

<sup>2</sup> *Mean barium value recorded for active wells operating in this watershed.*

<sup>3</sup> *Calculation does not consider attenuation of barium due to ion exchange with stream sediments, chemical precipitation or infiltration.*

Based on the likelihood of a large degree of natural attenuation and the availability of alternative treatment or disposal options for the small percentage of wells that will require such handling, the Department finds that it is not necessary to allow barium degradation to exceed the in-stream significance threshold of 480 ug/l in the upper Belle Fourche watershed. An NPDES permitting strategy for maintaining barium concentrations within the significance threshold includes:

- ! Limiting end-of-pipe discharges to 1800 ug/l and average in-stream concentrations to 480 ug/l as measured at the USGS gaging station on the Belle Fourche River below Moorcroft (station # 06426500). Under this option, 100% of the CBM wells in the watershed could discharge untreated water as long as the average in-stream concentration does not exceed 480 ug/l. It is likely that because of naturally occurring chemical precipitation, ion exchange and infiltration, the average in-stream concentration will not reach 480 ug/l.
- ! If the average barium concentration of four consecutive sampling periods equals or exceeds 480 ug/l, permitted discharges would be allowed to continue at up to 1800 ug/l for the term of the active permit. Effluent limits on new or renewed permits will be adjusted as necessary to bring the in-stream barium concentrations back within the significance threshold of 480 ug/l. For purposes of this calculation, sampling periods shall not be more frequent than monthly nor less frequent than quarterly.

**Segment 8. Lower Belle Fourche - The Belle Fourche Watershed below Keyhole Reservoir to the South Dakota state line.**

	Background Barium Conc. (ug/l) <sup>1</sup>	CBM Well Barium Conc. (ug/l)	Assimilative Capacity (ug/l)	20% of Assimilative Capacity (ug/l)	In-stream Significance Threshold (ug/l)	Projected Maximum Barium Conc. In-stream (ug/l)
Min						
Max						
Median	100		1900	380	480	
Mean		570 <sup>2</sup>				
Std Dev						
Low Flow	300	1800				1647 <sup>3</sup>
Median Flow	300	1800				1376 <sup>3</sup>
Median Flow	300	570 <sup>2</sup>				453 <sup>4</sup>

<sup>1</sup> Actual sampling data for barium is not available for this segment of the Belle Fourche River. Therefore, the median barium value for the adjacent upstream reach (Upper Belle Fourche) was used to determine available assimilative capacity and the threshold of significant degradation.

<sup>2</sup> Currently, there are no proposed CBM wells in the Lower Belle Fourche watershed. Value represents the average concentration of the combined existing wells in the upper basin (Upper Belle Fourche, Caballo Creek and Donkey Creek).

<sup>3</sup> Based on a mass balance calculation considering the maximum discharge from 3096 CBM wells at the referenced flow condition. This figure represents the combined total of wells in the Upper Belle Fourche, Caballo Creek and Donkey Creek watersheds. The median background concentration and the maximum allowable end-of-pipe concentration were used for this calculation. Calculation does not consider attenuation of barium due to ion exchange with stream sediments, chemical precipitation or infiltration. Actual resulting in-stream concentrations will be significantly lower. Also assumes all wells contain a barium concentration of 1800 ug/l. The figure represents the worst case for the associated flow condition.

<sup>4</sup> Calculation does not consider attenuation of barium due to ion exchange with stream sediments, chemical precipitation or infiltration.

Based on the likelihood of a large degree of natural attenuation and the availability of alternative treatment or disposal options for the small percentage of wells that will require such handling, the Department finds that it is not necessary to allow barium degradation to exceed the in-stream significance threshold of 480 ug/l in the lower Belle Fourche watershed. Currently, there is no CBM development proposed in the Lower Belle Fourche Watershed. The NPDES permitting strategy for maintaining barium concentrations that follows would apply to discharges in the watershed if a future development is proposed:

- ! Limiting end-of-pipe discharges to 1800 ug/l and average in-stream concentrations to 480 ug/l as measured at the USGS gaging station on the Belle Fourche River below Hulett (station # 06428050). Because actual CBM well quality data is not available for this

segment, the percentage of wells that will require additional treatment or alternative disposal cannot be calculated. It is likely that because of chemical precipitation, ion exchange and infiltration, the average in-stream concentration will not reach 480 ug/l.

If the average barium concentration of four consecutive sampling periods equals or exceeds 480 ug/l, permitted discharges would be allowed to continue at up to 1800 ug/l for the term of the active permit. New discharges would be limited to less than 480 ug/l at the end-of-pipe. For purposes of this calculation, sampling periods shall not be more frequent than monthly nor less frequent than quarterly.

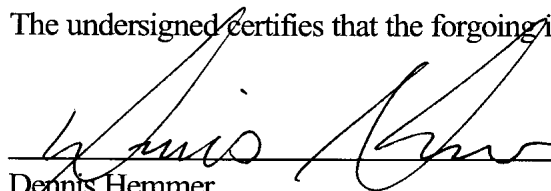
## **VIII. IMPLEMENTATION**

This document represents a final determination regarding barium antidegradation related to coal bed methane discharges in each of the associated watersheds. The described NPDES strategy for each watershed will be applied on each discharge permit issued without additional antidegradation review. The permit Statement of Basis would reference this findings document in each authorization.


These findings apply only to the authorization of NPDES permits for coal bed methane related discharges in the specified watersheds. Furthermore, they apply only to the issue of barium degradation and not to any other constituent or form of pollution. The background levels of barium that have been established in this review, however, will serve for the purpose of determining assimilative capacity and significant degradation relative to any future discharges from non-coal bed methane related activities in the covered watersheds.

## **IX. AUTHORIZATION**

The undersigned certifies that the forgoing information is correct:

  
Dennis Hemmer  
Director, Department of Environmental Quality

9-4-01  
Date

  
Gary Beach  
Administrator, Water Quality Division

9/4/01  
Date